Copy 1

Theoretical Factors Affecting the Long-Term Charter Rate for Tankers in the Long Run and Suggestions for Measurement

Zenon S. Zannetos

118-65

Theoretical Factors Affecting the Long-Term Charter Rate for Tankers in the Long Run and Suggestions for Measurement*

by

Zenon S. Zannetos

I. Introduction: A Model for Long-Term Rates in the Long Run

The purpose of this note is to put forth and analyze the factors that affect the determination of the long-term tanker rate in the long run and suggest some methods for measuring the effects of these factors. One of the most important determinants of the long-term charter rate is, of course, the short-term rate at the point of the transaction. The reason for this is that the short-term rate incorporates in it certain fundamental structural relationships between supply and demand that are valid over time, and are reflected in the operations of the tankship markets. Since operating in the spot market is a substitute for operating on a time-charter basis, these two alternatives are naturally related by marginal rates of substitution. The latter, however, are not independently determined because both the supply as well as the demand schedules for spot versus time charters are vitally interdependent. With the exception of a small percentage of tanker capacity that is used for marginal trades, such as grain, vegetable oils and molasses, the demand for tonnage on spot is the difference between the total demand for independent tonnage and the time-charter demand. The same

---

*This is part of a larger project on "The structure of Tankship Rates and Oil Prices in the Post World-War II Period" that this author is jointly pursuing with Professor Morris A. Adelman of the MIT Department of Economics. The author wishes to acknowledge the aid of the Ford Foundation for granting him a Faculty Research Fellowship for 1964-65 to pursue part of this research, and the MIT Sloan School of Management, for granting the necessary computer time and the research assistance of Hilliard Wood.

can be said of the supply side of the market. This circularity, of necessity, is reflected in the rates. As a result, with the exception of the uncertainty premiums that we will shortly explain, at any moment of time, spot and the long-term rates are interdependent. As in any other forecasting exercise where existing data and short-run indicators are used for conditioning expectations about the future, so are short-term rates used as inputs for decisions on long-term rates, and the latter for determining the long-term rates in the long run.

In using the short-term rate in a model for time-charter rates in the long run, we must therefore divorce the former from any short-run fluctuations that do not reflect basic structural relationships which are valid over time. Otherwise, the long-term rate that we will be determining will be a long-term rate in the short run. Consequently the model that we will propose will include only "normal" short-term rates.

Two basic models will be tested, a linear-additive and a multiplicative. The general form of the relationships is:

(1) $R_L = R'_s + aX_1 + bX_2 + cX_3 + dX_4 + fX_5 + E$, and

(1') $R_L = R'_s X^a_1 S^b_2 X^c_3 X^d_4 X^f_5 E$

where R'_s and the X_i are all some type of a function of time, as we will shortly indicate in detail, and E is a random error.

In the above formulations R'_s stands for the "certainty equivalent of the normal short-run rate" at the time the transaction takes place. This rate is not equivalent to the empirical market short-run rate because the market short-run rate may reflect at any moment of time market imperfections. We are here concerned with a rate that is based on the long-run supply

schedule of the industry. It includes the minimum necessary return to guarantee replenishment of the required investment and also reflects the normal conditions of uncertainty of employment. To the extent that no one will be encouraged to invest unless he expects to earn the minimum necessary return on his investment, R'_s may be based on the long-run cost of the marginal block of vessels at the time the transaction takes place.

The definition of what constitutes the "marginal block" of vessels is not intuitively obvious. It cannot refer to the class of the smallest vessels operating in the markets because these vessels are mostly used for special purposes such as for transporting oil to isolated harbors which are not equipped to handle larger vessels. Furthermore, vessels operating on time charters are usually used for transporting crude oil and not refined products. For the latter, smaller vessels are normally used because of constraints imposed by the size of markets. As a result, whenever at any moment of time, we wish to define the "marginal capacity" for time-charter purposes, we must think of the marginal vessels which <u>normally</u> operate in the crude trade for major routes and not of the most marginal vessels operating in the most marginal trade of the most marginal route.

Finally there is another requirement that we must impose on our definition before we calculate the normal short-term rate. The vessel chosen as marginal must belong to a class that represents at least 2-3 per cent of the total tonnage. If not, it will not be very influential in rate setting. Luckily this requirement can be easily met since tankers are built in sizes that belong to representative classes.

The impact of any errors in measurement because of the above assumptions concerning the determination of R'_s , or any imperfections and bias in the

basic statistic itself, will be corrected by variables X_1, and X_2, as we will shortly observe. If the model is to be used only for prediction and given that the partial interrelationships remain constant over time, only consistency is required in the assumption of a point of departure, because the model includes self-correcting (or compensating) features. We realize, however, that if we cannot solve this basic measurement problem to our satisfaction, the estimated quantitative impact of the various independent variables on long-term rates will be biased.

A. Two Aspects of Risk: Underemployment and Unemployment

One of the reasons for the difference between the normal spot rate under uncertainty and the time-charter rate (in both the short run and the long run) is what one may call the risk premium. Vessels that operate in the spot market run the risk of underemployment as well as unemployment, consequently R'_s must include a premium commensurate to these risks. Under long-term contracts these risks are shifted from the owner to the charterer.

1. The Risk of Underemployment

The risk of underemployment is caused by the inflexibilities of size. A large vessel reflects potential economies of scale which can only be realized if the proper co-ordination and information flow is achieved. In order to avoid costly delays and idle capacities, a careful and sensitive scheduling process must precede the utilization of facilities. This scheduling activity is costly and will only be undertaken of course if the benefits from the reduction of uncertainty surrounding the probable values of the expected output are greater than the cost of the co-ordinative system.

Another factor affecting underemployment and also entering into the co-ordinative system relates to the nature of ancillary facilities. In order that a charterer may utilize effectively tankers of let us say, 100,000 D.W.T., he must make sure that:

(a) The potential loading and unloading ports have berth facilities for 100,000 D.W.T. tankers. If not, one must must arrange for off-shore loading and unloading.

(b) The depth of the harbors, rivermouths and canals is sufficient for the "draft" of the vessel. The alternative here is to reduce the draft of the vessel by not loading it fully, and losing some of the economies of size through loss of capacity.

(c) The proper balance between receipts of crude oil and refining capacity is preserved. A tanker of 100,000 D.W.T. can provide in one trip enough crude oil for approximately two days of operation for a refinery of 350,000 barrels per day of throughput capacity, and for 35 days for a refinery such as the one operating in Everett, Massachusetts. Since the cost of transportation of refined products is much greater than that of crude oil, the location of refineries is influenced extensively by the proximity and size, of the markets these refineries aim to cater. On-shore storage facilities can provide some flexibility, and allow the use of larger tankers. Such flexibility, however, is costly because of the fixed investment involved and the evaporation which ensues.

The various technical-technological aspects of the ancillary facilities and the process of scheduling that we have just mentioned, affect no doubt the prior distribution surrounding the various degrees of utilization of the large tankers. The risk of underemployment is a function of the shape, mean, and variance of this distribution. The expected loss of underemployment given an information-co-ordinative system, plus the cost of the system itself

(including the cost of additional facilities that it requires) must be no greater than the part of the efficiency of large tankers that reverts to the charterer. Otherwise, the charterer will be better off in chartering smaller vessels and have a "continuous" delivery. In this way the co-ordinative system will be simpler and less costly, and the need for on-shore storage facilities will be extensively reduced because the vessels will serve as floating storage depots "en route" to their destination.

Although the probability of unscheduled delays due to breakdowns, weather, etc., and the consequent probability of interruption of the flow of oil to the refineries may be assumed to be the same for each vessel irrespective of size, and the probabilities surrounding the causes of these delays as well as the occurrences of delays per vessel over time, and among vessels may be assumed independent but not mutually exclusive, yet the expected cost of a given time delay of larger vessels may be greater. In other words and even if the expected value of time delays under alternative plans may be the same, yet the incidences of refinery interruptions will have different time profiles and each incidence will be of different magnitude. The larger the vessel is, the greater will be the discontinuity of refinery interruptions, and the longer the duration of each idleness under the assumptions postulated above. Consequently the expected costs may be different, as in the case of the "gambler's ruin".

Variable X_1 represents this risk premium of underemployment. It operates both on the short term[1] as well as the long-term rate and it obviously refers to the particularities of the chartered vessel. Since technology changes over time, we expect X_1 to be a function of the technological changes expected to occur over the charter duration.

---

[1] But see the special problems encountered in measuring the underemployment premium in the short run.

The sign of the coefficient of X_1 is expected to be negative in our formulation because we take as a reference point for R'_s the "marginal" vessels. For any submarginal or special purpose vessels the coefficient of X_1 is thus expected to be positive. There is only one possible exception that comes to mind. In cases of very depressed market conditions and given that all the ancillary facilities are scheduled on the assumption that large vessels will be normally used, the owners of unemployed small vessels may be willing to conceed a lower rate than that which prevails for larger vessels in order to compensate the charterer for the changes (and possible concommittant inefficiencies) that are introduced into his scheduling plans.

2. The Risk of Unemployment

Any vessel that operates in the spot market runs the risk of being unemployed a certain part of the year. This risk is not only due to frictional unemployment between the completion of contractual commitments[2] but also due to the particularities of the tanker markets. The particularities are conducive to fluctuations where periods of surpluses are followed by periods of excess demand. Most of these factors are explained in detail in The Theory of Oil Tankship Rates: An Economic Analysis of Tankship Markets especially in Chapter VII entitled "Characteristics of the Tankship Markets".[3]

[2] The common practice is for vessels to enter the market before the expiration of their commitment. Expectations concerning the trend of rates will determine the exact timing but in general, for vessels trading in the spot market, the time difference between contract and vessel delivery is an increasing function of the spot rate and ranges between zero and fifty days. Normally, the vessel will enter the market at the time it leaves the loading point for the final leg of its trip.

[3] Zannetos, Zenon S., The Theory of Tankship Rates: An Economic Analysis of Tankship Operations, MIT, Alfred P. Sloan School of Management, Working Paper 84-64, 363 pp. plus Appendices, September 1, 1964.

The seasonality of the petroleum products accentuates further the risk of unemployment. In order to meet the requirements of seasons of peak demand, it is necessary to have over the year approximately 9 per cent more transportation capacity, than what is necessary to meet the average demand. In other words, given the transportation requirements of any particular year, if these requirements were distributed uniformly over the year, the tonnage required to meet the demand would have been 91.7 per cent of what is normally necessary to meet peak demand and this because the demand is not uniformly distributed. Between the peaks and valleys of demand for transportation capacity of each year, there is a difference of 13 per cent of the average yearly capacity requirements. Unfortunately not very much can be done to smooth out shipments because the demand for fuel oil in winter months is not postponable. Consequently, although the capacity available at any moment of time may be sufficient to meet average yearly requirements, shortages and surpluses will appear over certain periods during any one year. Alternatively, if the industry makes plans for meeting peak demand requirements, at least seven months out of twelve the tanker markets will have surplus vessels. This is a piece of information the implications of which some oil companies fail to appreciate and do not usually consider in their plans, although they know that it exists. Always they plan on <u>average</u> yearly requirements and thus generate information that is biased. With the volatility of the tankship rates, whenever utilization reaches beyond 95 per cent of available capacity, a severe winter can cause rates to go easily from Intascale minus 55 to plus 50 (a three-fold increase) even though there is enough capacity to meet <u>average</u> demand. The rate increase may cause a flood of new orders and thus set up the beginnings of a rate cycle. The moral here of course is that the oil

industry should plan on the basis of the actual profile of demand over the year and not the average, since the transportation plans cannot be smoothed out.

We have chosen X_2 to represent the unemployment risk premium. This variable, unlike X_1 the risk of underemployment, operates only on long-term charters. Its coefficient is expected to be negative, because under a long-term charter agreement, the risks of unemployment are shifted to the charterer. The longer the duration of the time charter, the greater the reduction of the risk of unemployment facing the owner of a vessel. Consequently X_2 is a function of time.

B. Brokerage Fee Savings

On all transactions no matter whether these are for spot (single voyage), consecutive voyage or time charters, the brokerage fee is paid by the vessel owner. This fee is normally 1 1/4 per cent of the total rental involved (called "hire") times the number of brokers taking part in the transaction.

According to information obtained from industrial sources, most charters of all types:

(a) Are transacted through brokers, and

(b) Involve two brokers.

There are, of course, certain exceptions to these rules. For instance, the Japanese shipowners, who only recently entered the universal market, prefer to deal directly with the charterers (oil companies). These agreements, however, are a very small percentage of the total transactions.[4] Turning now

---

[4]Our model will still be valid in these cases because of the alternatives facing the owners. The Japanese practices, however, will tend to understate the brokerage fee saving and hence reduce the importance of X_3 in determining the long-term rate.

to the number of brokers who enter into the transaction we find that most shipowners list their vessels with both London brokers, since London is the central tankship market, and Norwegian or United States (New York) brokers. As a result the fee paid is normally 2 1/2 per cent of the charter hire and often goes as high as 5 per cent.

Given that the fee is a function of the total revenue represented by the agreement, as long as the percentage is fixed, it makes little difference to the owner whether he enters the market only once or many times over the life of his vessel. There are two exceptions that need to be examined, however, one of which as we will see results in a fee saving. One of these two considerations is the time-cost of money and the other the special discounts in the brokerage fee given to the owners of large vessels.

On first glance we observe that the larger the total represented by the charter agreement (because of the length of the time charter, the size of the vessel or the level of the rate), the greater is the financial strain imposed on the owner because of the brokerage fee. And this because the rental is received monthly while the brokerage refers to the total amount of the contract. Special arrangements are made, however, and the fee if large is spread over several months if not over the entire duration of the contract. So this consideration is not important from our point of view.

With the introduction of large tankers of 100,000 DWT and over, and charter agreements extending over 15-20 years, often special arrangements are made with the brokers and the fee may be reduced to as low as 3/4 per cent. As a result we must make provisions in our formulation to reflect the impact of brokerage fee savings on the long-term rate. Variable X_3 is intended to represent these savings and its coefficient is expected to be negative since the brokerage fees are paid by the shipowners.

C. Ability to Borrow on Long-Term Charter Agreements

A long-term charter agreement is very valuable for the owner of a vessel for another reason. It can be mortgaged. The steady income from the charter is used to liquidate the loan by being pledged as collateral. As a result the higher the rate and the longer the duration of the charter, the greater the "mortgageability" of the agreement. To the extent that we are concerned with the long-term rate in the long run and having taken care of the level of the rate in R'_s , we need only be preoccupied here with the impact of the charter duration on the long-term rate via the ability to borrow on the charter.

Banks have financed the majority of new vessels built subsequent to World War II on the basis of the security of the long-term charter agreements signed by the major oil companies. In the United States the normal practice has been to charge 5 per cent to 5 1/2 per cent for loans ranging from five to seven years. The maximum loan value of a charter has been usually 90 per cent of the amount that can be liquidated from the monthly "net hire," the latter being equal to the gross rental less all the operating costs that fall on the owner of the vessel. In other words if one takes the total monthly rent, subtracts out of it crew wages, stores and supplies, insurance, repairs and maintenance, takes 90 per cent of what is left and determines how much loan it can amortize over the life of the charter (present value of an annuity), then that is the loan value of the time charter.

Because banks are not willing or anxious to commit funds for a period longer than five to seven years, a new financing scheme has been devised where an insurance company accepts the mortgage beyond the 5th or 7th year, for a total of 12 years for the combined plan. Normally the bank will charge 5 per cent interest and the insurance company 6 per cent. If the charter agreement does not provide

enough for the repayment of 90 per cent of the original cost over 12 years then the owner is expected to provide a down payment of 20 to 25 per cent of the fixed investment. A net hire which does not yield a present value equal to 75 per cent of the cost of the vessel over 12 years is normally considered a bad risk and avoided. Especially if the charter agreement does not include escalation clauses for the costs that fall on the owner of the vessel. This does not mean, however, that a smaller loan may not be obtained.

In our formulation X_4 stands for the mortgageability of the long-term charters and its coefficient is expected to be negative.

D. Efficiency Premium of Vessels

Even though we are attempting to develop "the long-term rate in the long run" yet we cannot completely divorce ourselves of the characteristics of the particular vessels. And this because there is a tremendous difference between the operating costs of vessels of different sizes and propulsion. These differences are expected to continue with the continuation of technological changes. It must be remembered that in our model we took as a point of departure the normal rate of the marginal block of vessels. As a result, if we do not provide for the advantages of size, then our estimated long-run rate will be biased by the cost of the current marginal vessel.

We must therefore recognize that the more efficient a vessel is in terms of fuel consumption and speed, the greater the rate it will succeed in securing.. Let us remember that an efficient vessel under a time-charter agreement benefits also the operator. To the extent that the rental is in the form of a flat charge per dead-weight-ton (DWT) per month, the faster a vessel is the

greater is its potential capacity, and the lower its fuel consumption the lower the total cost for the oil carried. Both these factors reduce the cost per ton of oil delivered, and as a result the time-charter rates for the efficient and faster vessels must be greater. In this way vessels of the same size, but of different speed and fuel consumption, by securing different rates tend to equalize the cost to the charterer per ton of oil delivered.

Because the charterer is not assuming any "risks" or is in any way inconvenienced if he charters an efficient vessel, we do not expect any part of the efficiency premium to revert to him. The added carrying capacity emanating through efficiency--reduced space taken by bankers and more trips per year--although affecting the cost per ton delivered favorably, yet it is not of such a magnitude as to create inflexibilities of the nature covered by variable X_1. The efficiency is normally achieved through additional capital investment and added maintenance costs, such as those associated with diesel-engine propulsion, all of which are borne by the owners of chartered vessels. It is for these reasons that we expect these efficiency premiums to remain with the owners. Let us repeat again, however, that _in terms of a spot-rate equivalent_ these differentials will be fully accounted for, and other things equal rates per ton of oil delivered for vessels belonging to the same size class will be equalized in the market. Consequently the coefficient of X_5 representing the efficiency premium is expected to be positive, _if the long-term rate of our model is given in terms of dollars per DWT per month_. If we translate everything in terms of spot-rate equivalent, however, then we do not need to provide for X_5 because the spot rate is expressed in dollars per ton of oil _delivered_. There is only one aspect of X_5 which operates

in the long run irrespective of how the rate is expressed, and which we may wish to analyze. This aspect refers to the projected cost of fuel oil, and which we must reflect in X_5 since we are concerned with the long-term rate in the long run. Obviously the advantages of an efficient vessel are greater the higher the cost of the fuel oil and vice versa.

E. Summary of Factors Entering the Model

In developing our model for long-term rates in the long run we have included the following variables:

R'_s = the certainty equivalent of the short-term rate which is necessary under conditions of uncertainty to guarantee reinvestment in the industry in the long run. This rate is taken at the time of projected transaction

X_1 = the risk of underemployment introduced by inflexibilities of size, and the <u>expected</u> <u>net</u> <u>cost</u> of the ancillary co-ordinative system

X_2 = the risk of unemployment due to purely stochastic reasons and the seasonality of demand within any one year

X_3 = the brokerage fee savings that are realized by the owner because he does not have to resort to the spot market often

X_4 = the loan value of the long-term charter agreement

X_5 = the efficiency premium of the particular vessel

Now we turn to the method of estimating the value of the above variables.

II. Methods of Measurement and Estimation

The task of measurementis not an easy one, and in our case occasionally we have to resort to approximations. Often the latter will be somewhat biased, but

in the absence of unbiased estimators for our variables our only alternative is to devise a measure that will reduce the bias as much as possible.

Because all of the variables are not homogeneous it is necessary that we reduce them to a common denominator. It is proposed here, that we convert everything in terms of Inta-scale equivalent.

A. Estimation of R'_s

On the basis of observations of industrial practice we can unequivocally say that decision-making data are biased by averages. This does not necessarily imply that such information is eventually used or that in any way it affects market behavior. Nonetheless this practice destroys the usefulness of information, hides the action-motivating signals and also inhibits the development of an efficient planning and control system which is so urgently needed.

With the extensive economies of vessel size that the industry realizes, an average is meaningless if it encompasses the total tonnage. Only within a size class can we improve information by averaging. What we need is a statistic such that its expected value will be equivalent to the normal short-run rate under the conditions of uncertainty operating in the tankship markets. This rate although it must refer to the point of time the long-term transaction is to take place, yet it must be such that one can extend over time otherwise the predicted long-run rate will have a fixed point of reference and not be very useful.

In our estimation, R'_s must be based on the long-run cost curves of the industry. Specifically, it must reflect the rate which will justify a long-run investment in the marginal transportation capacity at the various points of time. The question now facing us is how do we obtain this rate.

We have already explained why such a rate must reflect the risks of unemployment which affect vessels operating in the spot market. The expected unemployment, $E(U)$, characteristic of the spot market has three components:

(a) The expected unemployment because of tie-ups $E(U^T)$

(b) The expected idleness due to the seasonality in demand during any one year, $E(U^S)$

(c) The "hidden surplus" which is caused by "slow downs" and extended repairs, $E(U^H)$

All three factors must be expressed as a percentage of total yearly capacity. Factor (a) may be approximated by the average yearly capacity lost due to tie-ups over the spot-rate cycle. For computational purposes this estimation process is:

$$E(U^T) = \sum_{t=1}^{n} \left[\sum_{i=0}^{1} U_i^T \, P(U_i^T) \right]_t P[\ ]_t \tag{2}$$

where U_i^T = the unemployment of different time durations (expressed as a percentage of a year), $P(U_i^T)$ = the probability of U_i^T

$P[\ ]_t$ = the probability of $\left[\sum_{i=0}^{1} U_i^T \, P(U_i^T) \right]_t$ over the time span of the spot-rate cycle.

We must notice in the above formulation that for any one year:

$$P(U_i^T) = C(U_i^T) / \sum_{i=0}^{1} C(U_i^T) \tag{3}$$

where

$C(U_i^T)$ = the total yearly capacity in DWT or T-2 equivalents that were idle for duration i (as a per cent of a year)

and of course

$\sum_{i=0}^{1} C(U_i^T)$ = the total available capacity operating and idle.

Another item that needs explanation is the summation over t . To the extent that any one year may not be representative enough to provide a good estimation of $P(U_i^T)$, we may choose a complete spot-rate cycle of n years and obtain an expected value of idleness over time. It is for this reason that we introduced $P[\ ]_t$ for $1 \leq t \leq n$.

The formulation as given above assumes that all vessels irrespective of size are equally affected by unemployment due to tie ups. Because there may be certain sizes of vessels which are not affected by idleness, we must find out if the probability of unemployment is uniformly distributed over vessels of various sizes. Theoretically, as well as from evidence presented in The Theory of Tankship Rates, there are reasons to believe that the smaller vessels are the first to be tied-up. We must, therefore, obtain some idea of the magnitude of the probabilities involved over the rate cycle. Once we determine the latter probabilities by size of vessels, we must then obtain the probability that the various sizes operate in the spot market, because we are ultimately interested in determining the risk premium of operating on a voyage basis.[5] Again in this case there are indications that the two major sectors of the market--spot versus time charters--are affected in different ways by the probability of unemployment. So the end result that we wish to obtain here and test whether it is different from the overall average, is the probability of unemployment of vessels of various sizes S_j applicable to the voyage (spot) market, v , only. Computationally for any year t this is:

---

[5]Note that this is what the owner avoids by operating in the time-charter market.

$$(4) \qquad E(U^{T}_{S_j,v})_t = \left[\sum_{i=0}^{1} U^{T_i}_{S_j,v} \; P(U^{T_i}_{S_j,v}) \right]_t$$

where:

$P(U^{T_i}_{S_j,v})$ is the joint distribution of the vessels in the various size categories, S_j, that were unemployed for i part of their potential yearly capacity $(U^{T_i}_{S_j})$, and also were operating in the voyage market $(S_{j,v})$. This joint probability is:

$$(5) \qquad P(U^{T_i}_{S_j} \cap S_j,v) = P(U^{T_i}_{S_j}/S_j,v)\; P(S_j,v) = P(S_{j,v}/U^{T_i}_{S_j})\; P(U^{T_i}_{S_j})$$

There are two major shortcomings with the degree of purity incorporated in relationship (4). The latter as formulated depends on the existence of refined data and the stability over time of the size distribution of the statistical universe. The first constraint we can overcome with a lot of work, but the second can neither be assumed because of technological changes, nor is it easy to establish its future nature. Therefore, there are two possibilities before us. We can: (i) relate the vessels operating in the spot market at time t to the variance of the size distribution of all vessels at time t and then test for stability of these relationships as well as of the probabilities of idleness over time, or at least over the spot-rate cycle, or (ii) assume that the probabilities of idleness are characteristic of the total spot market tonnage, the size distribution of vessels being such that over the rate cycle it leaves the probabilities or $E(U^T)$ invariant.

Under alternative (ii)[6] we look at all vessels in the spot market (C_v) versus all those operating in the long-term markets (C_L), and solve for $E(U^T_v)$ in the following general equation over the rate cycle:

$$E(U^T) = E(U^T_v) + E(U^T_L) \tag{6}$$

$$E(U^T) = P(U^T/C_v)\ P(C_v) + P(U^T/C_L)\ P(C_L) \tag{7}$$

where

$$P(C_v) = C_v/(C_v+C_L) = C_v/\sum_{i=0}^{1} C(U^T_i) \tag{8}$$

$$P(C_L) = 1 - P(C_v) = C_L/(C_v+C_L) \tag{9}$$

Factors (b) and (c), that is to say $E(U^S)$ the expected idleness because of the seasonality in demand during any one year and $E(U^H)$ the expected idleness caused by "slow downs" and extended repairs, are normally difficult to measure independently. The only way we can obtain a measure of (b) is to measure the combined impact of (b) and (c) and then subtract the contribution of factor (c).[7] So we will attempt to measure the contribution of both taken together. What we have in mind here is to measure the difference in transportation requirements between the high and the low season and express the surplus in terms of total yearly capacity. This we found to be 9 per cent.

---

[6] The assumptions behind (ii) seem to be the most appropriate because there exists relative homogeneity in the size distribution of vessels operating in the spot market.

[7] In the <u>Theory of Tankship Rates</u> there is a quantitative measure for (c).

Of the latter we must subtract any quantity that is reflected in factor (a). We can measure the influence of factor (a) on factors (b) and (c) by observing how the vessels go in and out of tie-up during the low and high seasons, and finally derive the combined effect of (b) and (c).

Having obtained the total expected unemployment (as a percentage of total yearly capacity), U , for vessels operating in the spot market, we are now ready to determine the rate R'_S which will guarantee the minimum return to the owners of marginal vessels[8] operating in the spot market.

1. Assumptions

To facilitate our preliminary calculations of R'_s we will initially assume that:

(i) The probability of idleness for any one vessel is uniformly distributed over the year. Although the probability of idleness is greater between April and October, the understatement of income during the first three and the last two months of the year will be offset by an overstatement during the middle months, in the process of discounting the revenue streams.

(ii) The probability of idleness is uniformly distributed over the vessels operating in the spot market at any moment of time. Although we may find that size and the probability of idleness are inversely related, to the extent that size and the probability of operating in the spot market are also inversely related a certain degree of size homogeneity is established in the spot market. Furthermore, we are interested here in the marginal capacity over time, consequently an assumption such as (ii) will not distort our calculations.

---

[8]The term marginal vessel as we explained previously does not necessarily refer to the smallest vessel (special purpose) but to the marginal size for normal transoceanic trade.

(iii) A specified run is given. This is necessary because we are measuring on the basis of an index (Inta-scale), and the latter cannot be determined unless the run is specified. Furthermore, given a specified index rate the structure of net backs to the owners of vessels of different sizes are different depending on the run. The major part of the difference is caused by the fixity of loading and unloading times and which become proportionately more important the shorter the run is.

2. The Rate

The desired rate R'_s is given by the following relation.

$$(10) \quad K_d = \sum_{t=1}^{n} \left[(1-\hat{U})C_m R'_S - OCg(t)\right]_t (1+i)^{-t} (1-TR) - \sum_{t=1}^{n} MP (1+i)^{-t}$$

$$+ \sum_{t=1} f(t)MP(1+i)^{-t} (TR) + \sum_{t=1}^{n} D_t h(t) (1+i)^{-t} (TR) + S_n (1+i)^{-n}$$

$$+ \left[I - \left(\sum_{i=1}^{n} D_t + S_n\right)\right] TR$$

In the above formulation:

K_d = The down payment

$1-\hat{U}$ = The probability of employment, $\hat{U}$ being the estimate of U as previously explained.

C_m = The monthly carrying capacity

R'_S = The unknown monthly rate in terms of \$/ton delivered that we are looking for

OC = The monthly out-of-pocket operating costs which may be a function of time $g(t)$ and include:

(a) Wages, Salaries and Supplies for the crew

(b) Insurance

(c) Maintenance

(d) Cost of Inspection (mod. 48). This cost is zero unless t is divisible by 48. And this because inspections are required every four years.

(e) Fuel cost and port charges, monthly average

(f) Repartiation costs (mod. 12)

t = The time which ranges from one month to n months, the life of the vessel

i = The cost of capital which in our case is 8 per cent per year. Since we have chosen to work with monthly periods we will use an approximation of 2/3 per cent monthly discount rate.

TR = The income tax rate

MP = The monthly payments for liquidation of the loan. These are assumed to be constant per month and include both capital and interest.

f(t)MP = The interest part of the monthly payments. It is a decreasing function of time, and we can calculate it easily. The formula giving us the capital part of MP for month k is: $(MP - L\,\tau/12)\quad(1+\tau/12)^{k-1}$ where L is the total amount of the loan, and τ the yearly interest rate. Hence the interest out of the kth monthly payment is:

$$(11)\qquad MP - (MP - L\,\tau/12)(1+\tau/12)^{k-1}$$

D_t = The monthly depreciation for income-tax purposes which is a function $h(t)$ of time unless the straight line method of depreciation is used.

S_n = The scrap value of the vessel at retirement n months from building it.

I = The total cost of building the vessel.

All the above refer to the marginal vessel chosen as a point of reference. Solving equation (10) for R'_S we obtain the normal short-term rate for our model of long-term rates in the long run.

Since our formulation starts at a fixed point of time and determines R'_S, it may be advisable if we include any changes in R'_S which may occur over time because of economies of scale. The latter no doubt will affect expectations concerning the "datum", that is to say the level of the normal spot rate, which will prevail over the druation of the charter agreement. What we have in mind here can be accomplished by introducing a function for technological change operating on R'_S . For example we may substitute for R'_S :

$$(12) \qquad R^*_S = \int_{t=1}^{n} \left[R'_S - (R'_S - R^n_S)(1-e^{-\zeta t}) \right]_t \, dt \; f[\;]_t$$

$$(13) \qquad = \int_{t=1}^{n} \left[R^n_S + (R'_S - R^n_S) e^{-\zeta t} \right]_t \, dt \; f[\;]_t$$

where R^n_S is equal to the estimated normal spot rate for the "marginal" vessel at the termination of the transaction. To obtain ζ we may set:

$e^{-\zeta t} = .05$ or $.10$, when $t = n$ the charter duration.

The above formulation assumes continuous technological change between $t = 0$ and $t = n$. If we are not satisfied with this assumption we can introduce a step function, or substitute R^t_S for R^n_S , and $e^{-\zeta n}$ for $e^{-\zeta t}$. It

appears, however, that a continuous function will suffice since the size composition of the fleet changes continuously and so does the size of the marginal vessel. Furthermore, the substitution of a discreet function will complicate the process of estimation and introduce errors that are much more damaging than those the assumption of continuity may possibly bring about.

The term $f[\ ]_t = P\left[R^n_S + (R'_S - R^n_S)e^{-\zeta t}\right]_t$ may be assumed to be equal to $1/n$, thus assigning equal weight to the normal rates of the various years over the duration of the contract. It is possible that the charterers may be biased and be consistently underestimating the future. From observations of their reactions, however, nothing can be said with confidence especially since the bias may be naturally reflected in R^n_S. As a result the uniform distribution of weights over time seems to be the most appropriate.

Finally a note on the reasons for choosing an average rate R^*_S. From equation (13) it can be seen that R^*_S is an <u>average</u> of the normal spot rates over the duration of the charter agreement. The reason for this is that the time-charter rate itself is an average (constant rate per DWT per month) consequently any basic datum such as R^*_S must be itself an average also.

To complete, therefore, relation (10) we substitute relation (11) for $f(t)MP$, R^*_S as given by (13) for R'_S, and solve for R^*_S since all the other values are known.

B. <u>Estimation of X_1</u>

The risk of underemployment X_1 is a function of size. Consequently, X_1 must reflect the amount of the economies of scale that is conceded to the charterer.

Instead of introducing merely size in X_1 which will give the variable static characteristics (fixed point), it may be better if X_1 is measured in terms of cost savings. Taking the marginal vessel size as a point of departure, we calculate the savings that accrue with size, express them in terms of $/ton of oil delivered and we assign this value to X_1. Obviously these calculations are intended to give us a flexibility in determining the long-term rate in the long-run. If we set $X_1 = 0$ then we obtain the normal long-term rate and if we base the value of X_1 on the difference between the cost of the marginal vessel and that of size S^*, then we are deriving a particular long-term rate.

In order to obtain these cost savings for any given size of vessels, we set up equations such as (10) for both the marginal vessel and the vessel under consideration and solve for the difference between the two short-term rates R'_S. Since we are not concerned with any other economies but those of size we must exclude from the operating costs fuel consumption and also eliminate speed and propulsion differences.

Variable X_1 operates also in the spot market. Consequently it is advisable that we obtain an estimate of its impact on the short-term rate, in order to check if it is a function of time.[9] In case it is, something quite probable, we can provide for an exponential decay of the difference over the lifetime of the long-term charter. (The impact of time may also be shown through a change in the marginal vessel and reduction of the future operating

---

[9] We are now in the process of estimating the risk of underemployment in the spot market and have faced a series of methodological issues. These will be reported as soon as the computer runs are analyzed.

advantages of large vessels). The amount of change through time can be approximated by the following form, which we may use for estimating X_1 :

$$(14) \qquad X_1 = ES_n + 1/n \int_{t=1}^{n} (ES_o - ES_n)_t e^{-\rho t} \, dt$$

where

ES_0 = The economies-of-scale advantage of the vessel to be chartered over the marginal vessel at the point of the charter transaction. This advantage is expressed in terms of $ per ton of oil delivered.

ES_n = The economies-of-scale advantage of the chartered vessel over the vessel expected to be marginal at the point of termination of the charter, n periods hence. Again ES_n is in terms of $ per ton delivered.

$e^{-\rho t}$ = The decay factor, where ρ is chosen so as to make $e^{-\rho t} \to 0$ as $t \to n$. Both n and t are measured in years. We may for example set $e^{-\rho n} = C$ where C equals .05 or .10 and solve for ρ .

We must stress once again that if one wishes to derive the normal long-term rate, then he must set $X_1 = 0$, and that in agreement with the dimension of the long-term rate, X_1 is the average risk premium due to underemployment over the duration of the charter agreement.

C. Estimation of X_2 the risk of unemployment

The risk of unemployment has been already found in the process of solving equation (10) for R'_S or R^*_S.[10] We noticed that for vessels operating

---

[10] R^*_S as shown in equation (12) , is set equal to R'_S in (10) to recognize the impact of technological changes on expectations.

in the spot market, the probability of unemployment reduces capacity by a factor $\hat{U}$. Under certainty of employment, the capacity realized is C_m and not $(1-\hat{U})C_m$, consequently the rate that is required to guarantee 8 per cent return after taxes now becomes $R'_S(1-\hat{U}) < R'_s$.

If then for each size class,[11] we solve the appropriate equation similar to (10) for the rate that will guarantee the minimum return on investment under uncertainty and under certainty, the difference between these two rates, which is $\hat{U}R'_S$ or $\hat{U}R^*_S$, reflects the value of the unemployment risk and will serve as an estimator of X_2.

Although the risk premium due to unemployment is a function of the absolute size of the charter agreement yet we do not have to allow for any such functional relation. And this because $R'_S(1-\hat{U})$ is in terms of \$ per ton of oil delivered and applies to each and every year the vessel is on time charter. There is another aspect of X_2 that we must consider, however, and this relates to the duration of the charter agreement. In order to preserve the flexibility of our model and in accordance with our treatment of X_1 we made X_2 a function of time. If we assume that the more immediate the security the more important it is, then we must provide for an exponential decay of the uncertainty premium with time. The mathematical function that we need in this case, must give us decreasing returns to scale because beyond a certain number of years the marginal contribution to security of an added year of time-charter duration is indeed of little value. One such functional relationship is:

---

[11]For the normal long-term rate we are interested in the class of "marginal" vessels.

(15) $$X_2 = R'_S \hat{U}(1/n) \int_{t=1}^{n} e^{-\gamma t} dt$$ where n is the duration of the charter.

Another formulation which may be more realistic, assumes that no owner will concede the whole uncertainty premium unless the length of the charter provides complete security. So for any charter of n periods the value of X_2 will be:

(16) $$(X_2)_n = R'_S \hat{U}(1-e^{-\gamma n}) ,$$ where $\gamma =$ is the decay rate and should be chosen so that $e^{-\gamma n} \to 0$ as $n \to 15$ years. The reason for this choice of n is that from analysis of time-charter transactions it appears that the rates level off between 12 and 15 years. So we may set γ so that 90-95 per cent of $\hat{U}R'_S$ is realized when $n = 15$. To do this we solve the following relation for

(17) $$e^{-15\gamma} = aR'_S\hat{U}$$

where a is .10 or .05 depending on what percentage of the uncertainty premium we decide to leave as residual.

D. Estimation of X_3 , the savings of brokerage fees

We will assume here that 2 1/2 per cent of the total rental involved in a transaction is the normal brokerage fee for spot charters. We will also assume that the minimum brokerage fee is 3/4 per cent. These quantitative limits have been obtained from oil companies.

Since the hire H is $H = f(nxS)$, that is to say a function of both the charter duration and the size of the vessel, the exponent of asymptotic convergence must take both into consideration. We will therefore assume that the savings in brokerage fee reach a maximum when both the duration of the charter approaches 15 years and the size of vessel 100,000 DWT.

One expression for X_3 , which assumes logarithmic proportionality with respect to charter duration and vessel size (increasing returns with n and S) is as follows:

(18) $$X_3 = (1.75H)^{\alpha n + \beta S} / \sum_{t=1}^{n} C_t ,$$

where ΣC_t represents the carrying capacity over the duration of the charter. To derive α and β we observe that:

(19) $$\text{Max } (1.75H)^{\alpha n + \beta S} = 1.75H$$

where:

(20) $$\alpha n = .75 \quad \text{when} \quad n = 15$$
$$\therefore \alpha = .05$$

and

(21) $$\beta S = .25 \qquad \text{when} \quad S = 100M \text{ DWT},$$
$$\therefore \beta = .025$$

The choice of the weights for n and S was dictated by the way H varies with respect to t and S . The range of n , the charter duration, is from 1 to 15 with every year doubling the yearly hire. Size, however, increases by a factor of only five from the size of the marginal vessel to 100M DWT. Hence the weights of 15 to 5 .

The fact that there is a probability of unemployment $\hat{U}$ for vessels operating in the spot market does not dictate any adjustments, because the rate under uncertainty R'_S is higher than the expected certainty equivalent $R'_S(1-\hat{U})$. As we have already explained, the brokerage fee is a function of the total charter hire which is a product of the time duration of employment

and the rate, given a vessel size. Consequently whether we have the product of reduced capacity $C(1-\hat{U})$ and R'_S versus full capacity C times reduced rate $R'_S(1-\hat{U})$ the product remains unchanged providing complete compensation on this score. There is one impurity that is introduced, however, by the difference between the long-term rate and R'_S due to the various X_i but its influence will be infinitesimal because the maximum brokerage fee savings is only 1.75 per cent of the total rental.

E. Estimation of X_4, the loan value of the long-term charter agreement

In order to measure X_4 we must make certain assumptions concerning the two polar alternatives. It seems logical to assume that no vessel will be built unless it can secure some type of a loan. We must notice that this assumption is not overly restrictive. If the potential owner is an independent with well established position in the industry, then the probability that he will be refused a loan is small. On the other hand given that his cost of capital is greater than the borrowing rate, the probability that he will refuse to take advantage of loan arrangements will likewise be small.

The two polar sets of provisions that we will assume are:

	Restrictive Plan No time Charter Pledged	Liberal Plan Time Charter of 12 years as Collateral
Down Payment as % of total cost	25	10
Duration of loan in years	8	12
Interest rate compounded monthly	6%	5% the first 5 years 6% last 7

Given the above two alternatives, we can then find the value of each different plan to the owner by discounting the various payment streams at 8 per cent. The total difference between the two we then divide by the total capacity of the vessel over its lifetime (20 years) and find the maximum loan value of the charter in terms of $ per ton of delivered oil capacity.

We must note that we do not need to develop a different rate for each different size of vessel. To the extent that we have postulated that each owner expects 8 per cent return on his investment, the difference in X_4 between vessels will be due to economies of scale. But the latter which affect the necessary investment per unit of capacity, we have already considered in X_1 and will consider one remaining aspect in X_5 . So for our purposes here X_4 is independent of size. We must however make X_4 a function of the length of the time charter as we have previously done in the case of X_2 . Hence we must introduce the following form:

(22) $$X_4 = V^L_R \, (1-e^{-\delta n})$$

where V^L_R represents the difference between the liberal and restrictive plans, n the duration of the time charter in years and $e^{-\delta n}$ represents the decay factor.

To find the value of δ we may set:

$$e^{-\delta n} = b \quad \text{where} \quad b = .05\, V^L_R \quad \text{when} \quad n = 12 \text{ years}$$

F. Estimation of X_5, the efficiency premium

As we have already explained, for vessels within the same size class, efficiencies due to fuel oil consumption and speed of travel, loading and unloading, are equalized in the market. Consequently, the time charter rate of relatively efficient[11] vessels is higher than that of the relatively inefficient by this efficiency premium. When translated therefore in terms of spot-rate equivalent, all rates for vessels within the same size class and for the same time duration at any point of time should be theoretically the same. One can attest this by going through the procedure of translation. This is not surprising, of course, because the charterer, being interested in delivered cost per ton of oil carried, is relatively indifferent of the particularities of the vessel.

If we now look at vessels of different sizes still at any fixed point in time and for charters of the same time duration, we are confronted with three consequences of size as these affect efficiency. These are:

1. Economies reflected in decreasing costs of shipbuilding per DWT of capacity.

2. Economies reflected in increases in transportation capacity more than proportional to increases in dead-weight tonnage. That is to say if we take the ratio of potential carrying capacity over size in DWT, we will find that the ratio is an increasing function of size.

---

[11] We must note that this efficiency criterion is partial and refers to fuel consumption and speed only. On the basis of this criterion a vessel may be efficient but yet inefficient on an overall basis if we consider the fixed investment, maintenance, insurance and crew costs associated with these features. Since the latter costs, such as investment, maintenance, etc., are borne by the owner but the advantages are realized by the charterer, we must consider only the part that is bargainable because only that can be reflected in the rate.

3. Inflexibilities of size as previously explained.

Of all the above factors, the first one is reflected in R'_S so we need not provide for it here. The process of translation of long-term rates, in terms of $ per ton of oil delivered, will take care of the second factor. Finally, the third factor has been considered in X_1 so it need not concern us here. We see, therefore, that all aspects of the efficiency premiums for vessels of all sizes at any fixed point of time have been properly considered.

Finally we look at the efficiency premiums over time and find that there is one aspect that merits consideration, and it refers to the operating costs. Of the latter, two stand out in particular, crew costs and fuel oil costs. These items represent a significant part of the total operating cost of tankships and have shown some tendencies for a downward trend. The crew costs tend to decrease in total, notper person employed, because of technological pressures, and the latter apply to all vessels operating at a given point in time. Obviously a lot of slack exists in operating practices, otherwise, reductions in the number of crew would not have been possible. As for the fuel oil costs, the pressures come from oil overcapacity, aggravated by new patterns of ownership composition and alternative sources of energy.

To the extent that the operating costs falling upon the owners of vessels chartered on a time basis are considered in detail in R^*_S, there is no further need for adjustment at this point. For the fuel oil, however, we must recognize any trends in future prices. Since the charterer pays for the oil fuel, the more efficient the vessel is the more he stands to benefit over

the life of the time charter if prices increase and vice versa. We must, therefore, introduce a variable X_5 to reflect this. A possible formulation is:

$$X_5 = R_f e^{-\eta n} \tag{23}$$

where R_f stands for the spot-rate equivalent cost for fuel consumption at the point of transaction, n is the duration of the time charter and η represents the % rate of growth or decline in fuel oil prices. The difficulty here lies in estimating an appropriate η . One solution is to base our estimation mainly on historic data in order to avoid excessive subjective value judgements.

To summarize then the above is the only provision that we must make for the efficiency premium and include in X_5 , because all the rest are either equalized in the spot-rate equivalent or else included in R'_S and X_1 .

Appendices

I. Technological Change and Rates

This note will further amplify on the impact of technological change on short-term as well as long-term rates. If we look at the formulation for R^*_S, we see how the expectation of more efficient vessels entering into future markets exerts a downward pressure on rates both in the short run and the long run. Starting with the latter, we observe that technology relegates into the marginal category vessels of larger and larger sizes. As a result $R'_S - R^t_S$ becomes larger and larger and R^*_S lower and lower. But there is another aspect of the technological impact that we must consider. Expectations for lower future rates R^t_S affect also the spot market, because the charterers tend to postpone chartering on a time basis and consequently force a lot of vessel in the spot market thus depressing the spot rates. That is why once a rate depression occurs the percentage of vessels seeking employment in the spot market increases and so does the average size of such vessels.

Although the postponement of time chartering activities may increase the demand for spot charters, yet the total increase cannot be greater than the total surplus created. Indeed, since the immediacy of need and time sensitivity of time chartering are not as great as in the case of spot transactions, the impact on the spot market of the withdrawals from the time-charter market is surplus producing. If we add to this the psychological impact of withdrawals on the operations in the spot market, we will find that the end result on spot rates is very depressing. This of course creates a circularity, because the spot rates as we have previously explained are used

as data for long-term charter rates in the short run, thus resulting in further rate declines. In the above lies the explanation of the following statements made by John I. Jacobs & Company Limited in their World Tanker Fleet Review of June 30, 1964.

> Automation in all forms continues to be the subject of incessant study, and judging from some of the rates currently being accepted for long-term Timecharters, Owners must be taking into their calculations fairly large savings in operating costs resulting from crew reductions. It seems regrettable that in the quest for business Owners even have to sacrifice the benefits which should accrue from technical advances.
>
> For all charters extending over a full year, almost irrespective of the number of years involved and whether on a time or consecutive voyage basis, Charterers set a common freighting standard for each tonnage category which is the bare minimum under favourable conditions, and invariably succeed in covering accordingly.

II. Uncertainty Premiums Over Time: Relationships between Spot and Long-Term Rates and Size of Vessels

As we have already explained, one of the ways the size of vessels affects rates, is through the uncertainty due to unemployment and underemployment. The unemployment problem is manifested mainly in the long-run and consequently it affects only the time charter rate. And this not because a vessel in the short run is never unemployed. On the contrary most of the tie-ups come from vessels operating in the spot market. These vessels are led to tie-up, after a period of search for employment while being idle in operational readiness. What we wish to stress here is the following. In

the <u>short run</u> a vessel is naturally either employed or idle. If idle it means that demand is lacking, rates are probably very depressed and any further decrease in spot rates will in no way alleviate the situation. If on the other hand potential employment does exist then the owner of a vessel may trade off part of his expected revenue to acquire security from unemployment. Security in this case is obtained by chartering his vessel on a time basis. Because the total out-of-pocket costs of larger vessels are greater--although these are decreasing when expressed in $ per unit of capacity--large vessels avoid the spot market whenever the choice exists.

In contrast with unemployment, underemployment is a very real problem both in the short run and the long run. If a large vessel operating in the spot market cannot be fully employed, and the alternative is idleness, it accepts employment for "part cargo", that is to say it travels partly loaded. Similarly if the owner of a vessel wishes to avoid underemployment over time by shifting the risk to the charterer, he must offer the latter an incentive by yielding some of the economies of size. The charterer of course, especially if it is an oil company, has more flexibility and may decide to use the vessel fully if the value of the capacity gained is greater than the total costs its use may create. These latter costs are reflected in special off-shore loading and unloading facilities, excessive storage requirements both at the loading and unloading points, travel around the Cape rather than through the Suez Canal whenever appropriate, and rescheduling refinery runs to mention just a few.

The underemployment risk should theoretically then cause at any moment of time, a wide range between the spot rate of a "handy" size vessel and the largest vessel operating in the particular route. The range will be a function of the size of the vessel and of the aforementioned costs that size imposes

upon the charterer. As ancillary facilities improve and markets expand, the constraints limiting the utilization of large vessels become weaker, and as a result we should expect that the range in spot rates for vessels of different sizes at any moment of time, will be closing. There are evidences that such a closing of the spread between rates occurred in the last few years, consequently it is advisable that we compare the impact of size on spot rates for 1960-1964 with that of the years 1955-1959.

In order to identify the changes in ancillary technologies, one could examine the changes in the depth of harbors and the number of the latter which can accommodate large vessels, the size distribution of refineries, the size of markets, etc., and attempt to estimate the cost associated with the consequent changes in storage capacities and the use of off-shore loading and unloading facilities. Also for the Persian Gulf/U.K. run where we have the Suez Canal limitations, we can obtain a sample of stratified observations for vessels that traverse partly loaded at going spot rates and thus derive the real rate per unit of available capacity. Also we could develop a frequency distribution of the sizes of the various vessels which have been utilized in the various runs and relate these to the total tonnage available by size classes. In this way, we can obtain an idea of what type of constraints operated in the various runs over time and how these changed. But even with all these refinements and efforts still the results will be qualitative. The universal character of the tankship market with all its geographic particularities, the dynamic day to day fluctuation in rates and the introduction of small sample errors, make any quantitative measurements of the

impact of the risk of underemployment on spot rates an impossible task. But we will have more to report on this matter on another occasion.[12]

The absence or the expectations concerning future removal of constraints will no doubt also decrease the spread between the time charter rates (in spot-rate equivalent) of vessels of different sizes at any moment of time. There is, however, another and more serious potential influence on the spread between long-term rates of a given time duration, and that is the threat of technological changes.

In the long run the spread between rates will be affected by the expectations governing the shape of the long run supply schedule. If technology changes fast and develops larger and larger sizes with concommitant economies of scale being realized, then of course one would expect the long-run supply schedule to shift downward and be more elastic at full capacity. It is at this point that constraints enter, and expectations concerning their removal over the lifetime of a time charter allows the expected efficiency of future vessels to overshadow that of the existing vessels. This is clearly seen in R^*_S. It is for these reasons that we need to examine the technological changes in both tankship building and tankship operation as well as the elimination of ancillary technological constraints in order to understand the significance of changes in the range of time-charter rates.

---

[12] We are now in the process of measuring these impacts. The immense difficulties involved in identifying the causes of the differences between rates of vessels of different sizes and the results of our efforts will be the topic of a forthcoming working paper.